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# Comparison of Banks and Ranking of Bank Loans Types on Based of Efficiency with DEA in Iran

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## Abstract

Banks as financial and service-provider institutions in a society have a decisive role in the circulation of money and wealth of a country, so they have a special place in the economy of each country. Considering the importance of lending in quality of banks return and econom-ic decisions and increasing competition in banks, analysis and research in this area is neces-sary. Accordingly, in the present study, a data envelopment analysis model was used to evaluate and select the optimal portfolio of banks' listed loans in Tehran Stock Exchange for 2017. Bank loans were evaluated using data envelopment analysis method and based on a set of banking criteria whith the use Gams software. In this method, banks are ranked based on the highest score and then the most efficient banks are selected. Finally, in order to evaluate the effectiveness and usefulness of the proposed method, a case study has been used in Iranian banks, which the results of performance evaluation of each type of loans and bank has been extracted. The results of the present study indicated that out of all the lending, Pasar-gad, Parsian and Saman Banks had the best performance and the Sarmayeh, Dey and Gardeshgari Banks had the poorest performance.

**Keywords**: Bank performance, Optimum loans portfolios, Efficient frontier, Inefficient frontier, Data envelopment analysis.

## 1 | Introduction

In any society, the bank is one of the main economic institutions. Fundraising and proper allocation and injection into industries are among the key tasks that banks play an important role. Undoubtedly, the proper allocation of these funds is a fundamental principle considered as integrated support of banks [2]. In addition, due to the limited re-sources of the bank and the increased demand for loans, the issue of optimal allocation of bank resources is crucial for the profitability and management of banks' resources. Further, designing or even using a bank loan model which is capable of tracking all real reactions and transactions will be extremely troublesome [6]. Moreover, a challenge for commercial banks today is their ability to understand large amounts of infor-mation and demonstrate useful knowledge to improve decision making process. Modern banking managers are overwhelmed by data. The sustainability of their banks depends on their ability to collect data from large volumes of data, extract useful information and apply this knowledge to their decisions. An intelligent information system provides managers with valuable information to reduce decision uncertainty and enhance the



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quality of banking ser-vices; the use of new technologies, therefore, can give the bank a competitive advantage and lead to higher performance [13]. Under the highly competitive environment in the financial services sector, banks are required to operate more efficiently. The chances of survival are more in banks operating at a high level of efficiency. High efficiency satisfies all stakeholders, while poor efficiency can lead to many undesirable results. This necessi-tates bank owners, consumers, regulators and investors to monitor the performance of banks [21]. As a financial institution, banks need to maintain their performance in order to operate optimally. One factor that must be considered is efficiency in perfor-mance [9]. Given the importance of this issue, a proper model should be developed to prevent the loss of bank capital. Data envelopment analysis is one of the tech-niques that can be of great help in enriching the literature in this field. In addition, it is im-portant to select portfolio of loans with allocation of capital among different assets by com-mercial banks. So choosing the best project portfolio from a specific set of investment pro-posals is a common and often important management issue [7]. On the other hand, one of the major problems of the banking system today is the non-current de-mands (past due, overdue and doubtful items) and how they are received. Increasing the vol-ume of non-current debts will have adverse effects on the efficiency of the banking network and economic indicators of the country. Accumulating volumes of non-current debts in banks and financial institutions will lead to inefficiency of its performance indicators. Also, lowering the profitability ratios and financial leverage and consequently leading to bank-ruptcy of banks and financial institutions [3]. Banking loans play an important role in efficient allocation of funds for economic growth. Investigating bank lend-ing behaviour is an important issue for financial stability and bank management. Obviously, it is important to examine the behaviour of banking loans, which is the problem of non-current loans as a major impediment to economic growth, which should be addressed [23]. The present study evaluates the loans of different banks by calculating and comparing the financial ratios based on the theoretical literature for each bank and also using the re-search performed in this field using a data envelopment analysis model. Furthermore, based on above mentioned issues, to address existing concerns, this method contributes to the effi-ciency and optimal selection of bank loans. Therefore, the purpose of the present study is to rank the banks based on the highest score and then select the most efficient banks. Finally, in order to evaluate the effectiveness and usefulness of the proposed method, a case study has been employed in Iranian banks that will yield important management results. Therefore, considering the literature review, the innovations that distinguish this research from other studies in the literature are summarized below:

All major headings are flushed with the left margin in Garamond. Headings 1 are capitalized, bold and in 15 fonts. Do not put a period after the text of the heading. Headings 2 are capitalized, bold and in 13 fonts. Headings 3 are sentence case and in 11 fonts. Leave one line above a major heading, and one line clear below before the start of the next paragraph or second-level heading. The whole paper should be written in "Garamond" font. The whole paper should be written in 11 fonts. Every paragraph should be justified. Line spacing at paragraphs should be multiple at 1.15 cm, and please leave one line space between two paragraphs. Please set the paper size as A4. Leave 1/75 cm margin at the top, 1 cm margin at the bottom of the page, 1 cm on both right and left sides. Please write your paper using Microsoft Office Word.

- *Unlike the coating analysis methods used in the studies, the method presented in this study can greatly differentiate between the options by applying efficient and ineffi-cient boundary information.*
- *According to the literature, this study is one of the first studies to examine banks' loans separately.*
- *Including criteria such as current and non-current loans (overdue, deferred, and sus-picious) and credit risk are other features of this research that distinguishes it.*

## 2 | Theoretical Fundamentals and Research Background

Yu et al. [22] conducted a study entitled performance measurement of a Taiwanese bank: a dynamic network coverage analysis approach of two systems. In this research, they have proposed a new method for constructing the non-convex meta-framework of the dynamic network data envelopment analysis. The results showed that the return on lending in the sample period has a downward performance and improving deposit activity has a positive effect on the overall performance of banks.

Boďa et al. [5] conducted a study as a model of a common hierarchical structure in data coverage analysis in bank branches. The study suggested that explicitly control the rate of comparison with a relatively flexible comparison limit to make more informative technical efficiency scores and economic goals possible. It is also a method of identifying the closest targets under the comparison constraint that is more achievable for inefficient units than traditional targets.

Sheikh Hassani et al. [18], measured the efficiency score using the cross-efficiency method in data envelopment analysis and its relationship with profitability and risk in banks listed on the Tehran Stock Exchange. Three results have been obtained. First, there is a significant relationship between credit risk and the efficiency of banks listed on the Tehran Stock Exchange. Second, there is a significant relationship between liquidity risk and the performance of banks listed on the Tehran Stock Exchange. Finally, they showed that there is a significant relationship between profitability and efficiency score of banks listed on the Tehran Stock Exchange.

Ahadzadeh Namin et al. [15] evaluated the performance of bank branches using the weight control approach in data envelopment analysis. After collecting data on 41 bank first-class branches, they evaluated using DEA model without bank first-class branches. Finally, using descriptive statistics and statistical tests showed that the weight limit applied improves the performance evaluation of the bank's first branches.

Firouzdehghan et al. [8] in a study called Portfolio Selection with high frequency data: fixed relative risk avoidance priorities and liquidity effect demonstrated that at different disadvantaged levels of risk, the expected portfolio's liquidity desirability is quite competitive and, in terms of expected usefulness, liquidity, and expected utility, relative to the benchmark.

Moghaddam and Ohadi [14] examined portfolio matching based on behavioral pattern at mean-variance boundary, which revealed that more than 70% of behavioral portfolio theory and behavioral portfolio theory circumstances were based on cumulative perspective model and mean-variance portfolio theory, respectively.

Bozorg Asl et al. [4] conducted a study on the effect of bank diversification and loans on bank opening (case study: private banks in Iran). This article examines the subject of private banks active in Tehran Stock Exchange including 12 banks, including: Bank Mellat, Saderat, Tejarat, Parsian, Eghtesad Modern, Pasargad, Sina, Hekmat, Dey, Sarmayeh, Postbank and Karafarin. The results of model estimation showed that there is an inverse relationship between diversification in asset and return on assets and there is no significant relationship between diversification in assets and return on assets.

Ali Heidari Boyouki and Khademi Zare [24] conducted a research on credit risk management using the development of data envelopment analysis. The method of data envelopment analysis has been developed in which using it, law firms that apply for banking loans located in different industries and sectors can be ranked both within the industry and across the company, the results of the proposed method show that the model has high power in ranking the grouped units.

Metawa et al. [13] in a study called Genetic Algorithm-based modeling to optimize bank decision making on lending, proposed an intelligent model based on Genetic Algorithm (GA) to organize bank loan decisions in a highly competitive and credit crisis constrained environment. The algorithm outperforms the most sophisticated methods of identifying the smartest tool that enables banks to reduce their loan review time by 12-50%, in addition, it increases the bank's profit by 3.9-8.1%.

Jat & Xoagub [11] proposed an automated artificial (fuzzy) logic-based machine system to help make bank loan decisions and explain why.

Agarana et al. [1] optimized bank loan portfolio management by using ideal planning techniques. This paper presents the results of bank loan portfolio optimization management. An operational research approach, objective planning, was applied to optimize the loan portfolio management of banks. The achieved result was an answer to how to handle bad loans or suspicious loans using a multi-purpose package.

Louzis et al. [12] Study the determinants of non-current debts separately for different types of loans (consumer loans, commercial loans and mortgage loans) in the Greek banking industry and concluded that both macroeconomic factors and quality of management are effective on loan quality.

### 2.1 | Research Questions

Q1. Which banks work best in each type of loans?

Q2. Which banks have the weakest performance in each type of loans?

Q3. Which banks have the best performance in terms of lending?

Q4. Which banks have the weakest performance in all lending?

## 3 | Methodology

This research is considered as applied research and is a descriptive survey based on the nature and method of data collection. It is a way of collecting library information. The statistical population of this research is the banks listed in Tehran Stock Exchange and Fars Stock Exchange for fiscal year 2017 that 15 banks were selected as statistical sample due to the availability of information. In this study, we used a set of banking criteria that were considered for input and output of the model. In addition, the proposed algorithm is coded in Gams software to obtain the corresponding score, namely efficiency and inefficiency score, and a Cplex solver is employed to solve the models. We also solved the model eleven times and evaluated for each loan individually and with different banks and we got the optimal loans, and finally solved for each individual model at different times.

### 3.1 | Theoretical Definition of Research Variables

**Type of loans:** In this research, the types of bank loans include: Foroushe aghsati, jeale, kharid dein, mosharekate madani, salaf, tashilate arzi, ejare besharte tamlik, which we examine separately below.

**Current loans:** Loans fall into the category that the borrower has fulfilled its obligations at maturity or up to one month after maturity and there is no problem in repaying the customer's debt to the bank. An increase in this index is appropriate for the bank. Therefore, this index is considered as output.

**Past due debts:** In this category, customer loans have not fulfilled their obligations up to one month after maturity. Therefore, this index is considered as an input index.

**Overdue loans:** Loans that fall into this category are divided into three sections based on the duration of the loans, short-term loans (less than one year), if the customer fails to fulfill its obligations up to 2 months after the transfer of the bank's debts to past due debts, bank debts are transferred from customer to overdue debts.

**Medium term loans (one to five years):** If the customer fails to fulfill its obligations by the month following the transfer of the bank's past due debts heading, the bank debts will be transferred from the Past due debts to the overdue debts heading. Long-term loans (over 2 years) where the reduction is appropriate for the bank, so this indicator is considered as an input indicator.

**Doubtful debts (bad debts):** Any debts that have expired more than 12 months are called doubtful debts. So increasing it increases debt and decreasing it is appropriate so this index is considered as an input index.

**Credit risk:** Credit risk can be described as a probable loss that occurs as a result of a credit event. A credit event becomes real when the ability of the contractor to fulfil its obligations changes. Credit risk is one of the most important risks generanking factors in banks and financial companies. This risk arises because the loans recipients are unable to repay their debt instalments to the bank. It is obtained by dividing non-current loans by total loans. Non-current amenities include past due, deferred and doubtful loans [20]. This index is considered as an input indicator.

## 3.2 | Data Envelopment Analysis Model

In this study, we used the method of Shen et al. [16] to evaluate different types of bank loans. Unlike other groups, these methods have the advantage that they are not limited to one specific group and can be applied to a variety of issues. In fact, in order to increase the discriminatory power of data envelopment analysis, Shen et al. [16] Used indexes that consider the distance between efficient and inefficient boundaries. In the presented method, Standard DEA and Inverted DEA are applied simultaneously to provide more information on boundaries [16]. This will increase the discriminatory power of coverage analysis and provide better rankings.

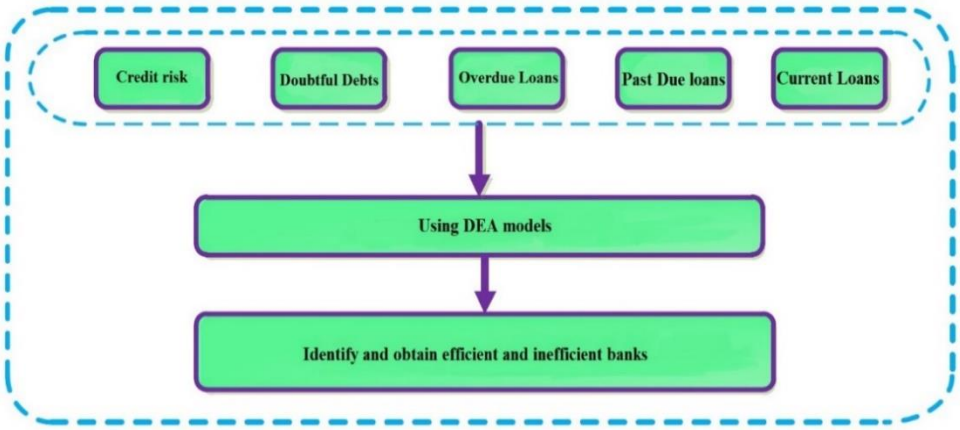


**Fig. 1. Approach used in the paper process structure.**

In this model, using a data envelopment analysis model, different banks are evaluated for selection based on a set of technical and economic criteria. The proposed envelopment analysis model is able to increase the distinction between options by using efficient and inefficient boundary information.

Data envelopment analysis is a non-parametric way to evaluate decision-making units based on observations. This technique manages complex relationships between inputs and outputs and does not require predefined weights. In addition, this method does not need to normalize input and output units and decision making. In our case, a specific supplier is considered as the decision making unit. By the way, this technique is widely used to identify and evaluate suppliers. In the following, the approach used will be explained. Suppose there are $n$ decision units so that their index is represented by$c$ $(c = 1, \dots, n)$.

Also, the inputs and outputs of the data envelopment analysis model for decision units are $x_{dc}(d = 1, \dots, g)$ and $y_{ec}(e = 1, \dots, q)$, respectively. The following model shows the Standard DEA model:

$$\text{Min } h_{bl}^{*} = \theta_l. \tag{1}$$

$$\sum_{c=1}^{n} x_{dc}\lambda_c \le \theta_l x_{dl},\ d = 1,\dots,g. \tag{2}$$

$$\sum_{c=1}^{n} y_{ec}\lambda_c \ge y_{el},\ e = 1,\dots,q. \tag{3}$$

$$\lambda_c \ge 0,\ c = 1,\dots,n,\quad \theta_l \text{ unconstrained.} \tag{4}$$

Also, the Inverted DEA model is as follows:

$$\text{Max } h_{wl}^{*} = \theta_l. \tag{5}$$

$$\sum_{c=1}^{n} x_{dc}\lambda_c \ge \theta_l x_{dl},\ d = 1,\dots,g. \tag{6}$$

$$\sum_{c=1}^{n} y_{ec}\lambda_c \le y_{el},\ e = 1,\dots,q. \tag{7}$$

$$\lambda_c \ge 0,\ c = 1,\dots,n,\quad \theta_l \text{ unconstrained.} \tag{8}$$

Where $\theta_l$ is the returns of amount of decision unit "l", $x_{dl}$ and $y_{el}$ are the studied inputs and outputs of the decision making unit (decision unit "l"), respectively and $\lambda_c$ is the weight of the doublet attributed to all inputs and outputs of the decision unit "c". Both models are solved for the decision unit "l" to obtain the efficiency scores $h_{wl}^{*}$ and $h_{bl}^{*}$. In other words, two models are solved $n$ times to determine the boundaries. In particular, Standard and Inverted DEA models generate efficient boundaries and inefficient boundaries, respectively.

The following figure shows the geometric mean of efficient and inefficient boundaries.

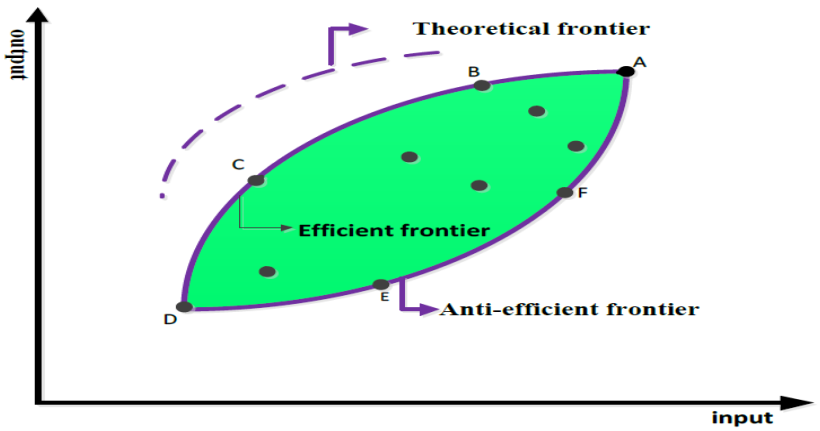


**Fig. 2. Graphics of efficient and inefficient borders.**

As we have seen, the standard data envelopment analysis model employs the best decision making units A, B, C and D in order to make the boundary efficient, the inverse model of data envelopment analysis employs the weakest D, E, F and A decision units. To form an inefficient border. The following index is calculated for each decision unit to use both boundary information efficiently and aggregate the efficiency scores of efficient and inefficient envelopment analysis models.

$$hi_l^{*} = \frac{\left[h_{bl}^{*} + (1 - \frac{1}{h_{wl}^{*}})\right]}{2}. \tag{1}$$

Note that if the decision unit "l" is located on the inefficient boundary (for example the decision unit F and E), then, $h^*_{wl} = 1$ and $hi^*_l = \frac{h^*_{bl}}{2} \leq \frac{1}{2}$, and if it's on both boundaries (for example decision unit A and D), that is $h^*_{wl} = 1$, $h^*_{bl} = 1$, then $hi^*_l = 1/2$. By the way, if the decision-making unit is focused only on the efficient boundary (decision unit B and C), then $hi^*_l$ will be greater than 0.5, which will be more efficient than the other units on both boundaries.

### 3.3 | Criteria Used in Data Envelopment Analysis

We define a set of criteria for the quality of a bank's loans and credit risk to evaluate and compare the efficiency of the types of banks' loans. The criterion in which the increase is desirable is considered as an output parameter and the criterion in which the decrease is desirable as the input parameter. Loans that manage acceptable scores are used as candidate loans in the bank. The defined criteria are as follows:

**Table 1. Criteria used in data envelopment analysis.**

| Variables | Input/ Output |
|---|---|
| Credit risk | Input |
| Past Due loans | Input |
| Overdue Loans | Input |
| Doubtful Debts | Input |
| Current Loans | Output |

## 4 | Analysis and Findings

The results of the important performance evaluation were extracted, which is very important for decision makers in this field, as follows.

**Table 2. Results of banks' rankings for ejare besharte tamlik loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_l$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.003 | 10 | 37.768 | 0.488 | 9 |
| DMU 2 | Ansar Bank | 1.000 | 1 | 250.698 | 0.998 | 2 |
| DMU3 | Iran Zamin Bank | 0.882 | 2 | 573.283 | 0.940 | 3 |
| DMU4 | Parsian Bank | 1.000 | 1 | 16360.902 | 1.000 | 1 |
| DMU5 | Pasargad Bank | 0.001 | 12 | 12.346 | 0.460 | 10 |
| DMU6 | Tejarat Bank | 0.243 | 6 | 32.964 | 0.606 | 6 |
| DMU7 | Hekmat Iranian Bank | 0.411 | 4 | 2.350 | 0.493 | 8 |
| DMU8 | Dey Bank | 0.329 | 5 | 1602.685 | 0.664 | 5 |
| DMU9 | Saman Bank | 0.004 | 9 | 6.121 | 0.420 | 12 |
| DMU10 | Sarmayeh Bank | 0.002 | 11 | 1.000 | 0.220 | 14 |
| DMU11 | Sina Bank | 0.2 | 7 | 1.000 | 0.350 | 13 |
| DMU12 | Kar Afarin Bank | 1.000 | 1 | 11.566 | 0.458 | 11 |
| DMU13 | Gardeshgari Bank | 1.000 | 1 | 260.583 | 0.998 | 2 |
| DMU14 | Melat Bank | 0.119 | 8 | 33.191 | 0.544 | 7 |
| DMU15 | Iran Post Bank | 0.565 | 3 | 260.583 | 0.781 | 4 |

As shown in *Table 2*, the options (2, 4, 12, and 13) in the Standard DEA obtained the same value as one. The coating analysis used also increased the power to distinguish between these options in order to better rank these options. We also found in *Table 2* that Parsian Bank had the best performance in terms of ejare besharte tamlik loans and that Sarmayeh Bank had the poorest performance in lending.

**Table 3. Result of banks rankings for jeale loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h_{bl}^*$ | Rank | $h_{wl}^*$ | $hi_l^*$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.051 | 9 | 1.000 | 0.025 | 15 |
| DMU 2 | Ansar Bank | 0.137 | 7 | 7.611 | 0.503 | 9 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 8.216 | 0.939 | 4 |
| DMU4 | Parsian Bank | 1.000 | 1 | 4511.740 | 1.000 | 1 |
| DMU5 | Pasargad Bank | 1.000 | 1 | 789.168 | 0.999 | 2 |
| DMU6 | Tejarat Bank | 1.000 | 1 | 2.094 | 0.761 | 6 |
| DMU7 | Hekmat Iranian Bank | 0.787 | 2 | 5.761 | 0.807 | 5 |
| DMU8 | Dey Bank | 0.221 | 5 | 3.147 | 0.452 | 12 |
| DMU9 | Saman Bank | 0.200 | 6 | 4.042 | 0.476 | 11 |
| DMU10 | Sarmayeh Bank | 0.262 | 4 | 2.652 | 0.442 | 13 |
| DMU11 | Sina Bank | 0.323 | 3 | 4.115 | 0.540 | 8 |
| DMU12 | Kar Afarin Bank | 1.000 | 1 | 1.000 | 0.500 | 10 |
| DMU13 | Gardeshgari Bank | 1.000 | 1 | 1.765 | 0.717 | 7 |
| DMU14 | Melat Bank | 0.074 | 8 | 1.300 | 0.152 | 14 |
| DMU15 | Iran Post Bank | 1.000 | 1 | 10.116 | 0.951 | 3 |

As shown in *Table 3*, the options (3, 4, 5, 6, 12, 13, and 15) received the same value in Standard DEA. We also found in *Table 3* that Parsian Bank has the best performance in terms of jeale loans and the Bank of Eghtesad Modern has the weakest performance. Also, options (1, 8, 9, and 14) did not get the necessary management points.

**Table 4. Banks ranking results for foroushe aghsati loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h_{bl}^*$ | Rank | $h_{wl}^*$ | $hi_l^*$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.043 | 9 | 4.539 | 0.411 | 11 |
| DMU 2 | Ansar Bank | 0.904 | 2 | 25.869 | 0.932 | 5 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 27.026 | 0.981 | 2 |
| DMU4 | Parsian Bank | 1.000 | 1 | 129.003 | 0.996 | 1 |
| DMU5 | Pasargad Bank | 0.007 | 10 | 1.000 | 0.003 | 15 |
| DMU6 | Tejarat Bank | 1.000 | 1 | 12.715 | 0.961 | 4 |
| DMU7 | Hekmat Iranian Bank | 0.843 | 3 | 11.238 | 0.877 | 6 |
| DMU8 | Dey Bank | 0.510 | 4 | 18.932 | 0.728 | 7 |
| DMU9 | Saman Bank | 0.098 | ۰ | 6.138 | 0.468 | 10 |
| DMU10 | Sarmayeh Bank | 0.047 | 8 | 2.330 | 0.309 | 13 |
| DMU11 | Sina Bank | 0.160 | 5 | 3.702 | 0.445 | 12 |
| DMU12 | Kar Afarin Bank | 0.007 | 10 | 1.000 | 0.004 | 14 |
| DMU13 | Gardeshgari Bank | 1.000 | 1 | 20.563 | 0.976 | 3 |
| DMU14 | Melat Bank | 0.418 | 5 | 3.605 | 0.570 | 8 |
| DMU15 | Iran Post Bank | 0.145 | 7 | 11.476 | 0.529 | 9 |

As shown in *Table 4*, the options (3, 4, 6, and 13) in the Standard DEA obtained the same value. In *Table 4*, we conclude that Parsian Bank has the best performance in terms of foroushe aghsati loans and Pasargad Bank has the weakest performance in terms of lending.

**Table 5. Result of bank rankings for tashilate arzi loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_l$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.202 | 11 | 7.645 | 0.536 | 10 |
| DMU 2 | Ansar Bank | 0.702 | 4 | 6.141 | 0.770 | 6 |
| DMU3 | Iran Zamin Bank | 0.362 | 8 | 4.507 | 0.570 | 9 |
| DMU4 | Parsian Bank | 1.000 | 1 | 1.000 | 0.500 | 13 |
| DMU5 | Pasargad Bank | 1.000 | 1 | 43.078 | 0.988 | 1 |
| DMU6 | Tejarat Bank | 0.516 | 7 | 14.779 | 0.724 | 7 |
| DMU7 | Hekmat Iranian Bank | 0.940 | 3 | 6.460 | 0.892 | 3 |
| DMU8 | Dey Bank | 0.067 | 13 | 1.274 | 0.141 | 14 |
| DMU9 | Saman Bank | 0.957 | 2 | 7.585 | 0.912 | 2 |
| DMU10 | Sarmayeh Bank | 0.046 | 14 | 1.000 | 0.023 | 15 |
| DMU11 | Sina Bank | 0.674 | 5 | 26.463 | 0.818 | 4 |
| DMU12 | Kar Afarin Bank | 0.224 | 10 | 5.787 | 0.525 | 11 |
| DMU13 | Gardeshgari Bank | 0.172 | 12 | 6.210 | 0.505 | 12 |
| DMU14 | Melat Bank | 0.613 | 6 | 18.066 | 0.779 | 5 |
| DMU15 | Iran Post Bank | 0.294 | 9 | 8.776 | 0.590 | 8 |

As shown in *Table 5*, options (4 and 5) in the Standard DEA obtained the same value as one. In *Table 5*, we conclude that Parsian Bank has the best performance in tashilate arzi loans and Sarmayeh Bank has the weakest performance in concessional loans. In addition, options 8 and 10 did not get the necessary management points.

**Table 6. Result of banks rankings for kharide dean loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_l$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.005 | 8 | 1.000 | 0.002 | 14 |
| DMU 2 | Ansar Bank | 1.000 | 1 | 324.937 | 0.998 | 2 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 9.846 | 0.949 | 6 |
| DMU4 | Parsian Bank | 0.993 | 2 | 2.918 | 0.825 | 10 |
| DMU5 | Pasargad Bank | 1.000 | 1 | 5.693 | 0.912 | 7 |
| DMU6 | Tejarat Bank | 0.725 | 4 | 98.721 | 0.857 | 9 |
| DMU7 | Hekmat Iranian Bank | 1.000 | 1 | 14.583 | 0.966 | 5 |
| DMU8 | Dey Bank | 1.000 | 1 | 216.859 | 0.998 | 2 |
| DMU9 | Saman Bank | 1.000 | 1 | 115.168 | 0.996 | 3 |
| DMU10 | Sarmayeh Bank | 0.270 | 6 | 1.000 | 0.135 | 13 |
| DMU11 | Sina Bank | 0.553 | 5 | 136.487 | 0.773 | 11 |
| DMU12 | Kar Afarin Bank | 1.000 | 1 | 24.615 | 0.980 | 4 |
| DMU13 | Gardeshgari Bank | 0.814 | 3 | 25.496 | 0.887 | 8 |
| DMU14 | Melat Bank | 1.000 | 1 | 336.758 | 0.999 | 1 |
| DMU15 | Iran Post Bank | 0.026 | 7 | 2.988 | 0.346 | 12 |

As shown in *Table 6*, the options (2, 3, 5, 7, 8, 9, 12, and 14) received the same value in Standard DEA. We also conclude in Table 6 that Bank Mellat has the best performance in lending kharide dean Loans and the Bank of Eghtesade Modern has the weakest performance in lending. Also, options (1, 10, and 15) did not get the necessary points for managerial comment.

**Table 7. Outcome of banks rankings for salaf loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h_{bl}^*$ | Rank | $h_{wl}^*$ | $hi_l^*$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.055 | 10 | 44.111 | 0.489 | 9 |
| DMU 2 | Ansar Bank | 0.08 | 9 | 10.989 | 0.455 | 12 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 14.219 | 0.965 | 2 |
| DMU4 | Parsian Bank | 1.000 | 1 | 539282.296 | 1.000 | 1 |
| DMU5 | Pasargad Bank | 0.667 | 3 | 9.479 | 0.781 | 4 |
| DMU6 | Tejarat Bank | 0.025 | 12 | 1.000 | 0.013 | 14 |
| DMU7 | Hekmat Iranian Bank | 0.556 | 4 | 7.899 | 0.714 | 5 |
| DMU8 | Dey Bank | 0.500 | 6 | 7.109 | 0.680 | 7 |
| DMU9 | Saman Bank | 0.400 | 7 | 16.002 | 0.469 | 11 |
| DMU10 | Sarmayeh Bank | 0.533 | 5 | 7.583 | 0.701 | 6 |
| DMU11 | Sina Bank | 0.004 | 11 | 1.000 | 0.002 | 15 |
| DMU12 | Kar Afarin Bank | 0.001 | 13 | 36.290 | 0.487 | 10 |
| DMU13 | Gardeshgari Bank | 0.733 | 2 | 10.427 | 0.819 | 3 |
| DMU14 | Melat Bank | 0.500 | 6 | 1.000 | 0.300 | 13 |
| DMU15 | Iran Post Bank | 0.163 | 8 | 118.422 | 0.577 | 8 |

As shown in *Table 7*, options (3, 4) in the Standard DEA obtained the same value as one. We also found in *Table 7* that Parsian Bank had the best performance in terms of salaf loans and the Bank of Tejarat had the weakest performance in lending. Also, the banks of Eghtesad Novin, Ansar, Sina, Tejarat, Saman, Kar Afarin and Melat did not get the necessary management privileges.

**Table 8. Banks rankings result for gharzolhasane loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h_{bl}^*$ | Rank | $h_{wl}^*$ | $hi_l^*$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.467 | 5 | 1.000 | 0.234 | 14 |
| DMU 2 | Ansar Bank | 1.000 | 1 | 4.820 | 0.896 | 5 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 7.047 | 0.929 | 4 |
| DMU4 | Parsian Bank | 1.000 | 1 | 1.957 | 0.745 | 7 |
| DMU5 | Pasargad Bank | 0.960 | 3 | 1.611 | 0.670 | 8 |
| DMU6 | Tejarat Bank | 1.000 | 1 | 1.000 | 0.500 | 11 |
| DMU7 | Hekmat Iranian Bank | 1.000 | 1 | 13.636 | 0.963 | 2 |
| DMU8 | Dey Bank | 0.631 | 4 | 2.325 | 0.600 | 10 |
| DMU9 | Saman Bank | 0.997 | 2 | 8.018 | 0.936 | 3 |
| DMU10 | Sarmayeh Bank | 1.000 | 1 | 1.000 | 0.500 | 12 |
| DMU11 | Sina Bank | 1.000 | 1 | 19.815 | 0.975 | 1 |
| DMU12 | Kar Afarin Bank | 0.163 | 7 | 1.293 | 0.195 | 15 |
| DMU13 | Gardeshgari Bank | 0.460 | 6 | 4.624 | 0.622 | 9 |
| DMU14 | Melat Bank | 1.000 | 1 | 1.000 | 0.500 | 13 |
| DMU15 | Iran Post Bank | 1.000 | 1 | 3.015 | 0.834 | 6 |

As shown in *Table 8*, the options (2, 3, 4, 6, 7, 10, 11, 14, and 15) received the same value in Standard DEA. We also found in *Table 8* that Sina Bank has the best performance in lending and karafarin Bank has the weakest performance in lending. In addition, Eghtesad Novin and Kar Afarin banks did not obtain the necessary managerial privileges.

**Table 9. Result of banks rankings for morabehe loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_l$ | Rank |
| DMU1 | Eghtesad Novin Bank | 1.000 | 1 | 57.299 | 0.991 | 2 |
| DMU 2 | Ansar Bank | 1.000 | 1 | 54.460 | 0.991 | 2 |
| DMU3 | Iran Zamin Bank | 1.000 | 1 | 24.115 | 0.979 | 4 |
| DMU4 | Parsian Bank | 1.000 | 1 | 1.000 | 0.500 | 10 |
| DMU5 | Pasargad Bank | 1.000 | 1 | 55.177 | 0.991 | 2 |
| DMU6 | Tejarat Bank | 0.410 | 6 | 15.249 | 0.672 | 9 |
| DMU7 | Hekmat Iranian Bank | 1.000 | 1 | 51.434 | 0.990 | 3 |
| DMU8 | Dey Bank | 1.000 | 1 | 19.938 | 0.975 | 6 |
| DMU9 | Saman Bank | 0.858 | 2 | 20.135 | 0.904 | 7 |
| DMU10 | Sarmayeh Bank | 1.000 | 1 | 85.642 | 0.994 | 1 |
| DMU11 | Sina Bank | 1.000 | 1 | 1.000 | 0.500 | 11 |
| DMU12 | Kar Afarin Bank | 1.000 | 1 | 21.350 | 0.977 | 5 |
| DMU13 | Gardeshgari Bank | 0.219 | 5 | 1.000 | 0.110 | 12 |
| DMU14 | Melat Bank | 0.403 | 4 | 10.125 | 0.652 | 9 |
| DMU15 | Iran Post Bank | 0.703 | 3 | 16.985 | 0.822 | 8 |

*Table 9*, many of the options in Standard DEA obtained the same value. We also conclude in *Table 9* that Sarmayeh bank has the best performance in terms of morabehe loans and Gardeshgari bank has the weakest performance in lending.

**Table 10. Outcome of bank rankings for mosharekate madani loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_l$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.107 | - | 2.287 | 0.335 | - |
| DMU 2 | Ansar Bank | 0.280 | - | 6.475 | 0.563 | 2 |
| DMU3 | Iran Zamin Bank | 0.059 | - | 1.000 | 0.029 | - |
| DMU4 | Parsian Bank | 1.000 | 1 | 43.780 | 0.989 | 1 |
| DMU5 | Pasargad Bank | 0.308 | - | 1.000 | 0.154 | - |
| DMU6 | Tejarat Bank | 0.065 | - | 1.172 | 0.106 | - |
| DMU7 | Hekmat Iranian Bank | 0.067 | - | 1.176 | 0.108 | - |
| DMU8 | Dey Bank | 0.240 | - | 1.419 | 0.268 | - |
| DMU9 | Saman Bank | 0.165 | - | 4.554 | 0.473 | - |
| DMU10 | Sarmayeh Bank | 0.090 | - | 1.000 | 0.045 | - |
| DMU11 | Sina Bank | 0.051 | - | 1.369 | 0.161 | - |
| DMU12 | Kar Afarin Bank | 0.079 | - | 1.213 | 0.127 | - |
| DMU13 | Gardeshgari Bank | 0.114 | - | 3.378 | 0.409 | - |
| DMU14 | Melat Bank | 0.118 | - | 1.509 | 0.227 | - |
| DMU15 | Iran Post Bank | 0.104 | - | 2.434 | 0.347 | - |

According to *Table 10*, most of the options did not receive the necessary managerial ranking, so what is clear is that these banks' non-current loans for mosharekate madani loans are much more than current loans, therefore, since these banks that did not get the necessary rankings cannot be ranked. Only Ansar and Parsian banks gained the necessary rankings.

**Table 11. Banks ranking results for mozarebe loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_i$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.010 | - | 2.541 | 0.308 | - |
| DMU 2 | Ansar Bank | 0.111 | - | 30.446 | 0.539 | 2 |
| DMU3 | Iran Zamin Bank | 0.062 | - | 18.921 | 0.505 | 6 |
| DMU4 | Parsian Bank | 1.000 | - | 339.836 | 0.999 | 1 |
| DMU5 | Pasargad Bank | 0.077 | - | 25.263 | 0.519 | 3 |
| DMU6 | Tejarat Bank | 0.051 | - | 1.000 | 0.025 | - |
| DMU7 | Hekmat Iranian Bank | 0.035 | - | 11.580 | 0.474 | - |
| DMU8 | Dey Bank | 0.004 | - | 1.000 | 0.002 | - |
| DMU9 | Saman Bank | 0.014 | - | 4.375 | 0.393 | - |
| DMU10 | Sarmayeh Bank | 0.004 | - | 1.000 | 0.002 | - |
| DMU11 | Sina Bank | 0.003 | - | 1.000 | 0.001 | - |
| DMU12 | Kar Afarin Bank | 0.063 | - | 20.219 | 0.507 | 4 |
| DMU13 | Gardeshgari Bank | 0.018 | - | 1.182 | 0.086 | - |
| DMU14 | Melat Bank | 0.005 | - | 1.612 | 0.193 | - |
| DMU15 | Iran Post Bank | 0.065 | - | 18.626 | 0.506 | 5 |

According to *Table 11*, most of the options did not receive the necessary managerial ranking. So the obvious thing is that the non-commercial loans of these banks in mozarebe loans are much more than the current ones. Therefore, these banks that did not get the necessary rankings cannot be considered rankings. Only Ansar bank, Iran Zamin, Parsian, Pasargad, Kar Afarin and Post Bank earned the required rankings.

**Table 12. Banks ranking result for total bank loans.**

| Standard DEA | | | | Inverted DEA | DEA method of Shen et al. [16] | |
|---|---|---|---|---|---|---|
| DMU | bank | $h^*_{bl}$ | Rank | $h^*_{wl}$ | $hi^*_i$ | Rank |
| DMU1 | Eghtesad Novin Bank | 0.202 | 11 | 7.645 | 0.536 | 11 |
| DMU 2 | Ansar Bank | 0.702 | 4 | 6.141 | 0.770 | 7 |
| DMU3 | Iran Zamin Bank | 0.362 | 8 | 4.507 | 0.570 | 10 |
| DMU4 | Parsian Bank | 1.000 | 1 | 1.000 | 0.921 | 2 |
| DMU5 | Pasargad Bank | 1.000 | 1 | 43.078 | 0.988 | 1 |
| DMU6 | Tejarat Bank | 0.516 | 7 | 14.779 | 0.724 | 8 |
| DMU7 | Hekmat Iranian Bank | 0.940 | 3 | 6.460 | 0.892 | 4 |
| DMU8 | Dey Bank | 0.067 | 13 | 1.274 | 0.141 | 14 |
| DMU9 | Saman Bank | 0.957 | 2 | 7.585 | 0.912 | 3 |
| DMU10 | Sarmayeh Bank | 0.046 | 14 | 1.000 | 0.023 | 15 |
| DMU11 | Sina Bank | 0.674 | 5 | 26.463 | 0.818 | 5 |
| DMU12 | Kar Afarin Bank | 0.224 | 10 | 5.787 | 0.525 | 12 |
| DMU13 | Gardeshgari Bank | 0.172 | 12 | 6.210 | 0.505 | 13 |
| DMU14 | Melat Bank | 0.613 | 6 | 18.066 | 0.779 | 6 |
| DMU15 | Iran Post Bank | 0.294 | 9 | 8.776 | 0.590 | 9 |

As can be seen from *Fig. 3*, options 4 and 5 in the Standard DEA obtained the same value as one. We also found in *Table 12* that Pasargad bank, Parsian, and Saman bank had the best performance in total lending and Sarmayeh bank had the weakest performance in lending loans. In addition, the banks did not receive the necessary management approval.

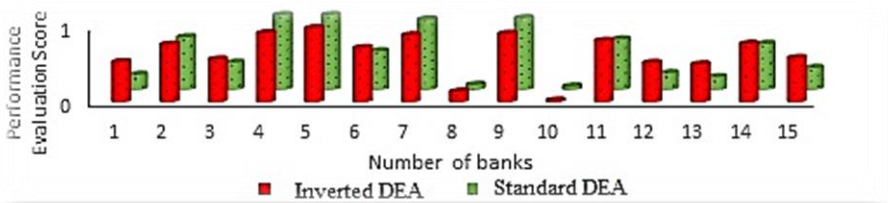


**Fig. 3. Comparison of rankings for all banks' loans.**

Further information on boundaries enhances the power of the DEA's assessment division. Based on the performance appraisal perspective, the minimum satisfaction score for the proposed index is considered; in other words, these DMUs with index values greater than 0.5 are selected as candidate banks. Based on

the results in the tables above, the candidate banks are selected as the candidate bank for the optimum loans to select the optimal loans to obtain the necessary management privileges. Based on the performance results, the minimum allowed score for the considered index ($hi_l^*$) is 0.5. In other words, units with an index value greater than 0.5 are considered as candidate and optimal banks.

To confirm the ranking obtained by the data envelopment analysis model, we use a non-parametric test called Spearman rank correlation method [17]. This method calculates the rate of positive correlation between the rankings obtained by the standard envelope analysis model and the model presented by the following criterion:

$$\rho = \frac{6 \sum id_i}{n(n^2 - 1)}.$$

$d_i$ displays the difference between the ranks of the proposed method for decision maker i with the two methods mentioned. In this respect, we set the null hypothesis $H_0$ against the alternative hypothesis$H_1$.

$H_0$: There is no positive correlation between the rankings obtained from the coverage analysis presented and the Standard DEA.

$H_1$: There is a positive correlation between the rankings obtained from the coverage analysis presented and the Standard DEA.

For this experiment, we assumed a confidence level (i.e. 1-α) of 0.97. The assumed test statistic and p-value were 0.949. Because the p-value is lower than the assumed value of zero, H_0 is assumed to be an effective link between the Standard DEA ranking and the DEA used, thus, the validity of the obtained results is correct.

## 5 | Sensitivity Analysis

In this section we are going to review the criteria used and the goal is to know to what degree these criteria matter, that is, by changing each criterion, or by increasing or decreasing each criterion, how the banks' optimality and efficiency will change. This helps decision makers in the field to determine which criteria are most important in their decisions. In addition, it is also useful in selecting the optimal basket because of the importance of the criteria; so for this we have evaluated several inputs and outputs. In other words, we kept one criterion constant and solved the model for the rest of the criteria and selected the one that made the least changes to the options and worked best. The results showed that the current loans criterion had the most effect and the expected demands at the end of each day had the least effect on the optimal portfolio selection and model changes. *Fig. 4* shows the ranking results of the criteria in order of importance.

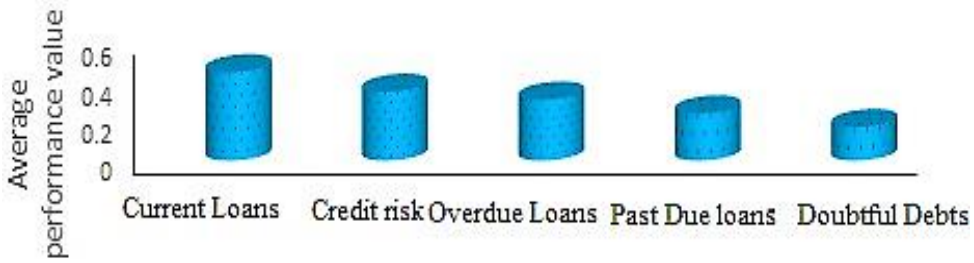


**Fig. 4. Ranking result of the criteria used.**

## 6 | Conclusion and Suggestion

Banks and financial institutions are the most important economic institutions in countries whose economic growth and development depends on their performance and efficiency. Therefore, evaluating

the performance and efficiency of banks and comparing them with each other in making decisions is essential. Preventing non-performing receivables at banks' concessional loans or planning to collect these receipts will increase bank revenue and profitability and increase bank resources.

In this regard, in this paper, a data envelopment analysis model is used to evaluate and select the optimal portfolio of banks' loans; different loans of banks were evaluated using data envelopment analysis method based on a set of banks criteria. In this method, banks were ranked based on the highest score and then the most efficient banks were selected. To this end, we were able to increase the distinction between decision-making options by applying the new data envelopment analysis method. Following on with a Spearman nonparametric hypothesis test that evaluates the degree of positive association between the rankings obtained by the standard envelope analysis model and the model presented, we were able to claim that there is an effective relationship between the rankings of Standard DEA and the DEA used [16]; therefore, we can conclude that the results of the coating analysis model presented [16] are correct and the results are confirmed. According to the first and second research questions, the results of *Table 2* indicated that Parsian bank performed the best and the Sarmayeh bank had the weakest performance in granting ejare besharte tamlik loans, the results of *Table 3* in granting jeale loans showed that Parsian bank had the best performance and the bank of Eghtesad Novin had the weakest performance, the results foroushe aghsati loans in *Table 4* show that Parsian bank had the best performance and Pasargad bank had the weakest lending, Also the results of *Table 5* of tashilate arzi loans showed that Parsian bank had the best performance and Sarmayeh bank had the weakest performance, *Table 6* kharide dean loans showed that Mellat bank performs best and the Eghtesad Novin bank performs poorly, the results of *Table 7* on the issuance of salaf loans indicate that Parsian bank performs best and Tejarat bank performs poorly, also, according to *Table 8*, in terms of gharzolhasane loans, demonstrates Sina bank performs best and Kar Afarin bank performs poorly, the results of *Table 9* of the sale against morabehe loans. Showed that Sarmayeh bank performed best and Gardeshgari bank performed poorly, furthermore, *Table10* and *Table11* on mosharekate madani loans and mozarebe loans indicated that banks had non-current loans more than their current loans and did not receive the necessary rankings. According to question 3 and 4 of the survey, *Table 12* shows the total loans of banks that the results showed that Pasargad, Parsian and Saman banks had the best performance in total lending, Sarmayeh, Dey and Gardeshgari banks, the weakest performance in lending. Compared to similar domestic surveys, Sudani [19] ranked banks and financial institutions based on the Cummins International Index, in which the Eghtesad Novin bank was identified as the best bank. In addition, [10] investigated the efficiency of public and private banks based on e-banking indices using Data Envelopment Analysis in which the results of the evaluation of the scale efficiency and its calculations at the end of the fiscal year 2010 indicate that Refah, Saman, Melli, Pasargad, Sina, Sarmayeh, Saderat, Tejarat, Sepah, Parsian, Melat, Maskan, Keshavarzi and Eghtesad Novin banks have been inefficient. Moreover, tosee Saderat bank, Kar Afarin, Post Bank, Sanat & Madan bank were identified as efficient banks, and among these four, efficient banks have been identified as the leading bank in providing electronic services in 2010 using the Anderson-Peterson Toseh Saderat Bank. Identification, measurement, qualitative and quantitative assessment as well as risk planning are essential for banks and financial institutions. Failure of banks to pay attention to credit risk leads to an increase in non-performing loans and in more advanced stages leads to bankruptcy and financial crisis for banks and credit institutions.

It is recommended to improve banking performance:

1. Systematic review and smartening of banks' concession loans status and bank customer validation.
2. Adherence to international standards in the field of non-commercial loans and concessional loans.
3. Holding specialized training courses for granting and receiving applications using modern methods.
4. Optimal portfolio creation of loans to reduce non-current claims and optimal credit policy.

## Suggestions for Future Research:

This study is one of the new research in the area of loans portfolio optimization. Therefore, for future research, enrichment of literature can be expanded in different ways.

For example:

1. Using decision making techniques such as hierarchical analysis, TOPSIS, etc. to optimally select loans.
2. Using multipurpose mathematical models to increase banking efficiency and risk reduction and optimize loans in Iranian environmental conditions.
3. Rankings and validation of customer types based on credit history.
4. Prioritizing the factors affecting the performance of banks listed in Tehran stock exchange.

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